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Study of Blast Furnace Stave Cooler Based on Heat Transfer Analysis

A thesis Submitted in partial fulfillment of the requirements for the award of the degree of

Master of Technology

in

Mechanical Engineering
(Thermal Engineering)

By

PRASHANT KUMAR AZAD

ROLL NO: 213ME3422

Department of Mechanical Engineering
National Institute of Technology Rourkela
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Under the guidance of

Prof . S . K. SAHOO

Department of Mechanical Engineering

National Institute of Technology Rourkela

Rourkela,2015

CERTIFICATE

This is to certify that the thesis entitled, "Study of blast furnace stave cooler based on heat transfer analysis" submitted by **PRASHANT KUMAR AZAD** in partial fulfillment of the requirement for the award of the degree of Master of Technology Degree in Mechanical Engineering with specialization in Thermal Engineering at the National Institute of Technology, Rourkela (Deemed University) is an authentic work carried out by him under my supervision and guidance.

To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other University/ Institute for the award of any degree or diploma.

Prof.S.K.SAHOO

Department of Mechanical

Engineering NIT Rourkela

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I express my deep sense of gratitude and indebtedness to my supervisor Dr. S. K. Sahoo, Professor of Department of Mechanical Engineering for his extensive support throughout this project work. His timely help, constructive criticism, and conscientious efforts made it possible to present the work Contained in this thesis. Working under him has indeed been a great experience and inspiration for me.

I would also like to thank **Mechanical Department** specially **Dr. M. K. MOHARANA** who has given idea about project**.** I express my sincere thanks to Mr. Tapas ranjan mohanty, Mohammed rayed farooqui and shaibu, PhD Research Scholars.

Date:

Place:NIT Rourkela **Prashant Kumar Azad**

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ABSTRACT

The life of blast furnace is increase due to technology of furnace cooling very important method for metallurgical industry. Blast furnace mathematical model of stave cooler has been developed for heat transfer analysis and compare to experimental. Using ANSYS® *software calculating the heat transfer and temperature of stave cooler. The result calculating using software* ANSYS® *and compare with blast furnace placed in* RSP *with experimental model.*

Heat transfer stave cooling of blast furnace has been done at different temperature from 575k to 1675k the result is compare with experimental for better result, in the stave cooling of blast furnace nitrogen and nano fluid (Al_2O_3) *also as a cooling fluid in the place of water.*

Keyword:-Stave cooler, temperature, Blast furnace, nitrogen.

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CONTENT

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LIST OF FIGURE

Description

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LIST OF TABLE
Description

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Nomenclature

K Thermal Conductivity of material, (W/mK)

Cp Specific heat of fluid, J/kgK

L Total length of stave, m

A Area of stave,m^2

m Mass flow rate ,(Kg/s)

q,, Heat flux experienced at hot face of stave, (w/m2)

Q Heat extracted by the stave ,(w)

dT Temperature difference (K)

Re Reynolds number

D Diameter of cooling pipe,(m)

Greek symbols

μ Daynamic viscosity,(Ns/m2)

ρ Density of fluid and solid,(kg/m^2)

υ Kinematic viscosity,(m2/s)

φ Rayleigh Dissipation Funtion

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CHAPTER 1

INTRODUCTION

In the blast furnace stave is cooling device for cooling the refractory lining stave having number of coil one or more than one coil. In the blast furnace refractory lining is installed in inner part of blast furnace to guard the steel shell and keep the inner profile and another type stave i.e copper stave is establish in the high thermal lode of blast furnace, in the Fig .1.1 shown stack to bally thermal load. Combustion is take place inside the blast furnace due to this large amount of heat is generated, inside the blast furnace lining cooling is effective technology for producing products. Hence due to copper stave cooler save from subsequent burning and overheating. Inside blast furnace very large amount of heat is generate so due to this heat cooling is important thing to save the furnace, water is a cooling medium for extracting the more heat inside the blast furnace. To protect the increase temperature of shell. There are so many methods for cooling of blast furnace shell. The staves are manufacture of cast iron, now in the place of cast iron copper stave are use. Which is very high conductivity and heat flux cast iron stave is 50% lower than copper stave. Campaign life of blast furnace by cast iron staves cooling which is not obey extra heat load. Copper stave show effective and good for overcome the extra hear and load.

Presently a day, cooling boxes of distinctive size, number and outline were utilized for exchanging warmth of the heater to a cooling medium in conjunction with shower cooling. Impact heaters with cooling stave of cast iron are working since 19 century. Stave of cast iron cooling was initially a Soviet revelation from where it made a trip at first to India and Japan. By 1970, cast iron stave cooling have achieved overall acknowledgement. Since the presentation of

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these stave coolers cast iron, the advancement work of impact heater cooling got quickened and today a wide mixture of coolers are accessible for the inner cooling of the heater shell to suit compelling state of anxiety in a present day vast superior impact heater.

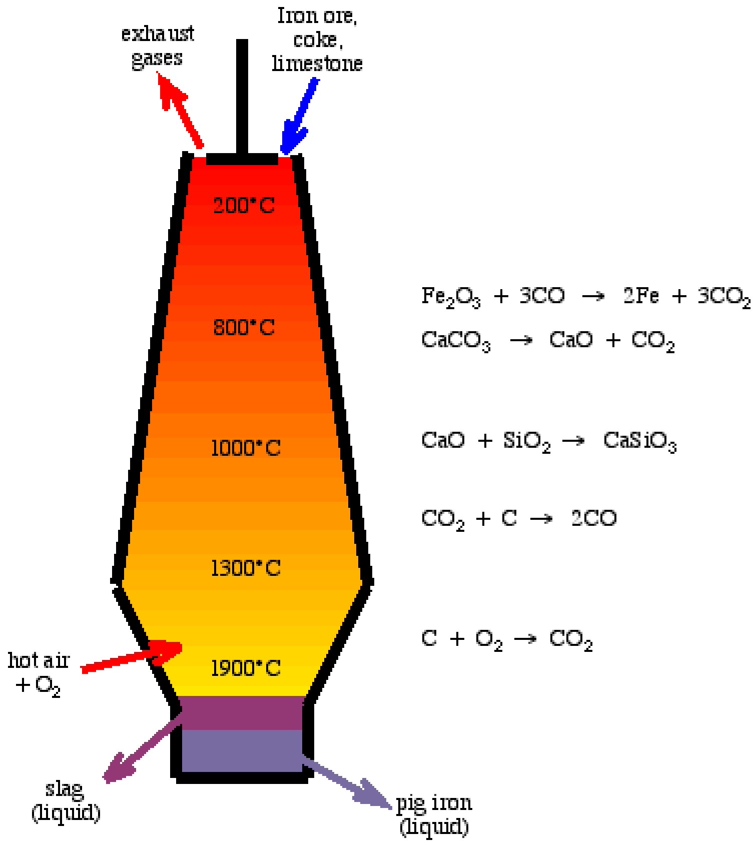

Figure 1.1 Thermal Zone of Blast Furnace [24]

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1.1Types of Cooler

1.1.1 Plate cooler

In Europe plate cooler has been utilized as a part of all furnace heater. Plate coolers are for the most part made by either welded or cast in electrolytic copper. The typical plate sizes are 500 - 1000 mm long, 400 - 800 mm wide and give or take 75 mm high, which is demonstrated in beneath Fig.1.2. Plate cooler has kept in the zones with high warmth heaps of impact heaters particularly in the bosh and lower stack areas, arrangement of plate cooler demonstrated in underneath Fig.1.3 and 1.4.Copper level coolers have a more noteworthy consistency of material properties over the complete cooling component. These coolers are intended to keep up high water speeds all through the cooler, consequently have an even and high warmth exchange coefficient. The copper level plate coolers for the most part have different channels with maybe a couple autonomous chambers. One of the plans of capper level plate cooler has six go with single chamber. These coolers are basically welded to the impact heater shell to guarantee gas tight fixing Minimum misfortunes of water weight are guaranteed in both the funneling and the component itself The figure of a common copper level plate cooler configuration.

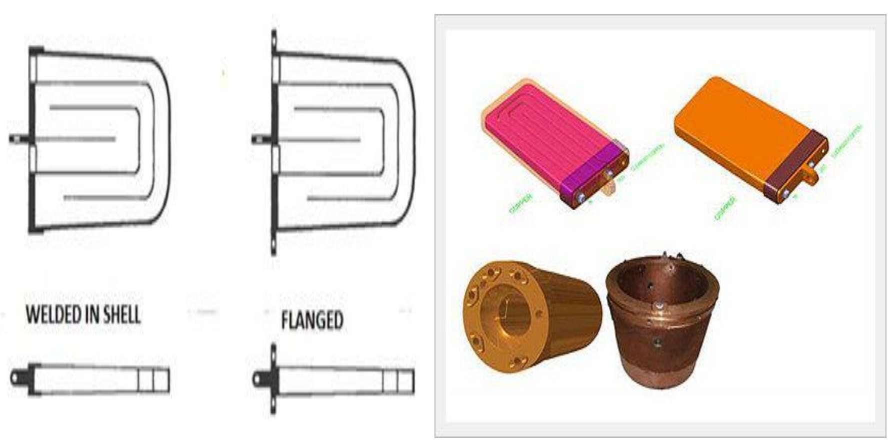

Figure 1.2 plate cooler

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1.1.2 Cigar cooler

For unique blast furnace applications, Cigar Coolers can be either thrown or manufactured in a wide range of measurements or lengths, the configuration of Cigar cooler indicated in beneath Fig.1.5. These are additionally called as copper coats. Cigar coolers are utilized as a part of between the plate coolers when more escalated cooling is obliged or there is additionally dividing of the level plate coolers, which is demonstrated in Fig.1.6. These are additionally utilized for enhancements to the current cooling framework amid a campaign. cooler is by and large machined by strong copper bar to frame a barrel shaped center and a solitary channel is included by penetrating and stopping. Cigar coolers are ordinarily continued the middle lines between adjoining level plate coolers on a flat and vertical plane. For the premise of establishment of a cigar cooler typically a tube shaped opening is penetrated through the heater shell and existing headstrong coating with a center drill. The cigar cooler utilization builds the cooling framework range and keeps the recalcitrant covering to concoction and mechanical assault component.

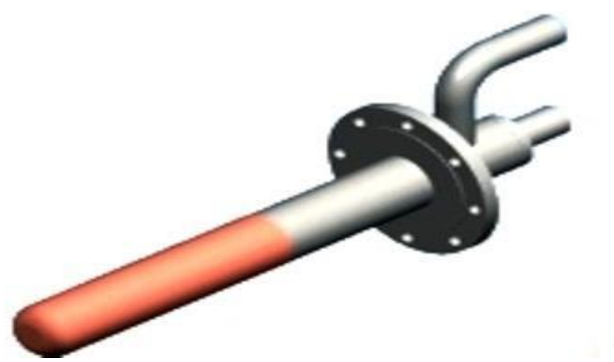

Figure 1.5 Cigar cooler

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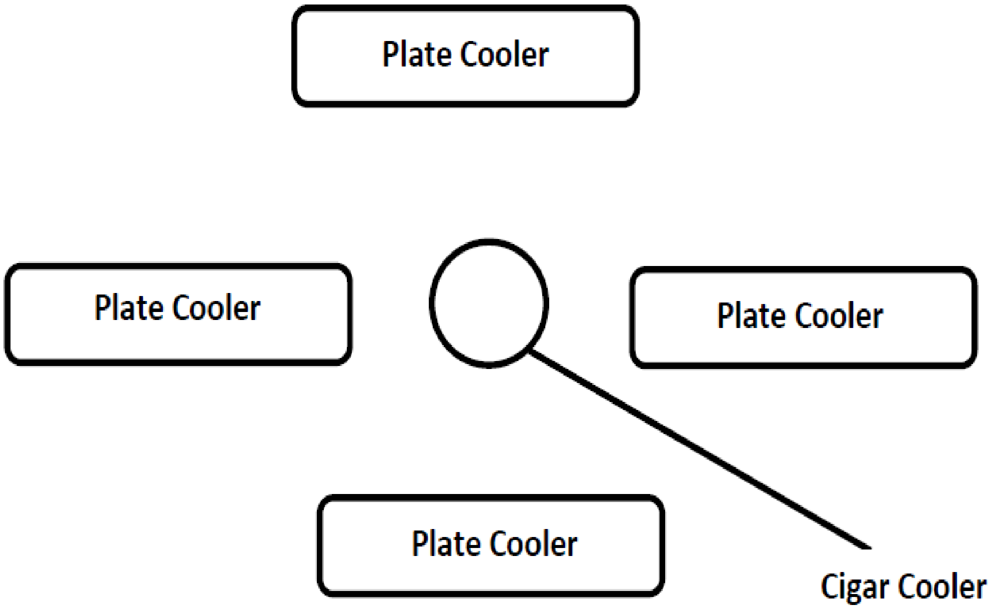

Figure 1.6 Arrangment of Cigar Cooler

1.1.3 Stave cooler

Copper stave were produced by Japan and Germany in the mid 1990s yet the more noteworthy number of the establishments is in or after 2000. Dimension of copper fight are 1640mm, 900mm and 200mm length, breath and tallness respectively. Typical outline of fight cooler demonstrated in underneath Fig.1.7.Copper fight are use in the area of bosh, paunch and lower stack to adapt to high warmth burdens and vast variances of temperatures. Stave cooler of Japan are thrown copper stave, however German copper fights are moved copper plates having close external resiliencies and with penetrating accomplished for cooling entries. Bored and stopped copper stave are normally intended for in arrangement straight line at four water pipes at top and

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four pipes arrangement in a straight line of water pipes the base. Interior funnel loops made by Monel, copper or steel.

1.1.3.1Types of stave cooler

Smooth Surface stave cooler – It having great warm conductivity and basic structure the hot face is smooth face. It is primarily utilized as a part of the front of tuyere and internal coating of BF hearth cooling.

Common Brick stave cooler- Use of common brick stave cooler is in bosh, lower part, stack and middle part. High alumina brick, silicon carbide brick is brick inlaid. Spacing lined refectory brick of stave is also known as hot face.

Common Ramming stave cooler- The hot face of stave is dividing lined pigeon tail with smashing unmanageable materials inside, and is fundamentally utilized as a part of bosh, gut and center and lower piece of stack.

Complete Cover Brick stave cooler- To enlarge the volume of furnace stave is fully enveloped by bricks of thin or non liner structure. This in mostly use in belly, stack and bosh,

1.2 Cooling Process of Blast Furnace- Water is originated from abnormal state tank of plant to the stave cooler at high speed because of gravitational power. These stave cooler are composed in a shut circle as opposed to the routine open frameworks. This permits the channel work to be synthetically cleaned, and by controlling water science all through the crusade this clean surface can be kept up, accordingly guaranteeing greatest warmth exchange. The primary capacity of the cooling arrangement of impact heater is to cool the heater shell and keep it from overheating and

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resulting smolder through. To achieve this, the cooling framework must have the capacity to take up the overabundance warmth produced by the heater and stacked onto the shell. This warmth will lift the shell and covering temperature too high if the cooling framework is not viable in dissipating it. Through the years, the improvement of cooling frameworks has gotten a lot of consideration, particularly in the most recent two decades. Two principle contenders developed for shell cooling, with still no unmistakable point of interest apparent. The principal of these is the alleged cooling boxes, or here and there also called level plate coolers. The second is the solid metal stave, which get awesome consideration particularly in Japan. Where level plate coolers, as the name portrays, are level plates that are orchestrated evenly into the heater shell, stave can be depicted as level plates stacked parallel and flush to within the shell and are cooled by an inherent channeling game plan.

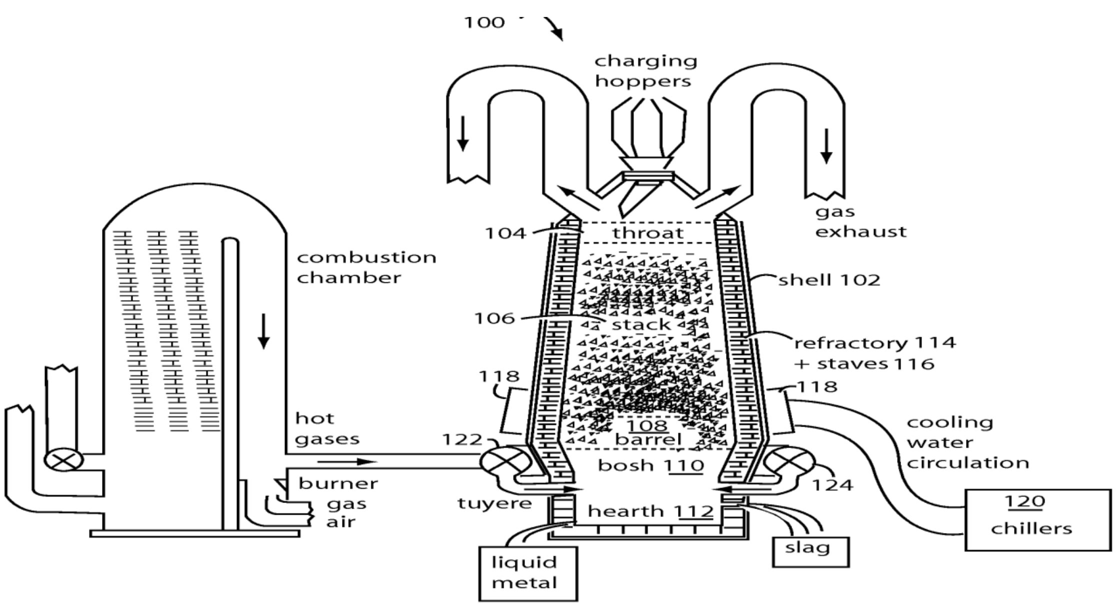

Figure 1.7 Stave cooler with lining [25]

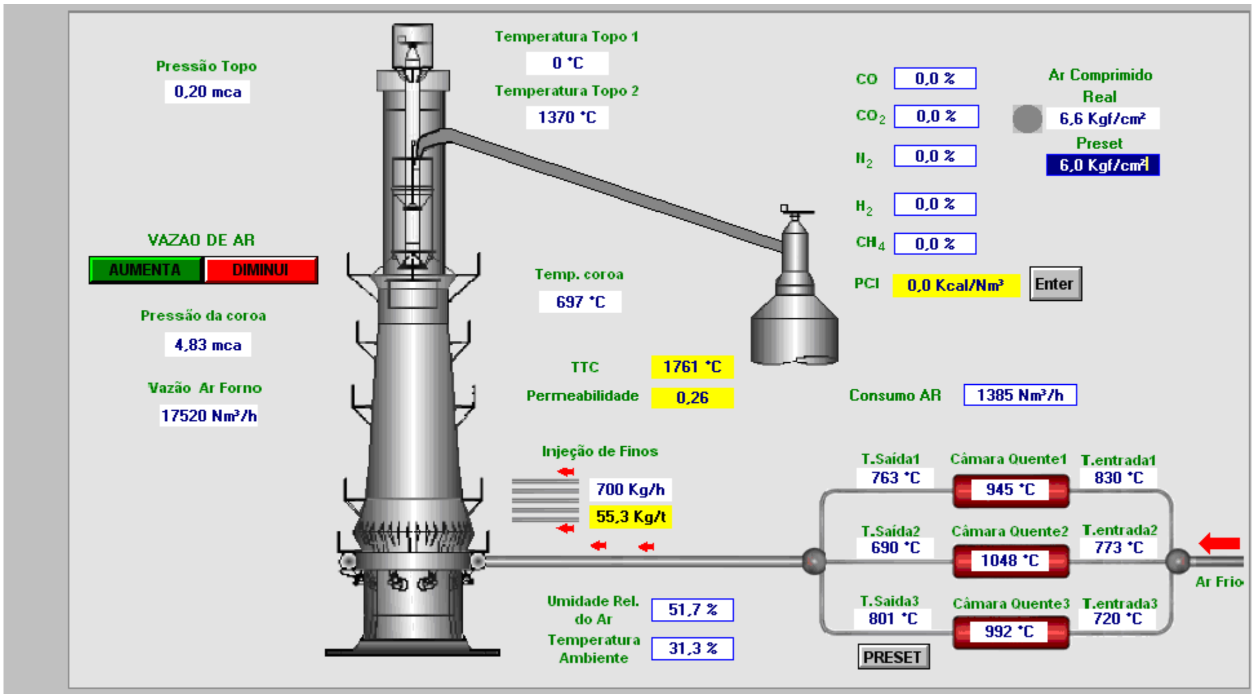

Figure1.8 Blast furnace processes flow diagram [24]

1.3 Objective of Present Work

1. To examine the behavior of stave material at various load conditions.

2. Design the stave cooler with 3-D model.

3. From experiment to calculate the temperature difference

4. The experimental model used in RSP(Rourkela steel plant), the numerical result is compare with experimental result of RSP.

5. In the place of water for cooling nitrogen and nano fluid is use.

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CHAPTER 2

LITERATURE EEVIEW

[1] Y. KO et al. He have analyzed the Thermal Behavior in upper –Hole Area. Thermal properties of mud-core is found, convection heat transfer coefficient of cast able and bricks of spool have a great effect on the top hole area temperature distribution they developed hearth model, which can estimate the trend of thermal behavior by manning thermal properties and they found temperature distribution of tap-hole area

[2] Akash Shrivastava and R.L. Himte. Using heat transfer analysis he study stave cooler of blast furnace. The cooling of blast furnace by using two different type of skull in the lining material as well as two different type of bricks are considered, first they had chosen imperceptible thickness then other is certain thickness, the consideration of thickness in millimeter (mm), so temperature load from 773k to 1573k the found that lining is better than other for heat extraction when use two different type of skulls.

[3] Anil Kumar et al. He takes two other type of lining material for modeling of three dimensional blast furnace cooling stave and this analysis i.e high alumina bricks and silicon carbide brick. Stave with skull is used at different gas temperature from 773k to 1573k for the lining material. In the cooling process water temperature is taken 303k. Then result is concluding that thermal stress and maximum temperature of hot face are minimum in alumina brick and higher in silicon carbide. So he select silicon carbide is more effective then alumina.

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[4] W.Lijun et al. For modeling of three dimensional stave of blast furnace uses ANSYS. The increasing of velocity of water and reducing the temperature of water is not economical. The thermal stress and maximum temperature in the stave is control properly by adjusting operating conditions of blast furnace, coating layer gas flow is operating conditions, cooling channel, lining material and inter distance, gas clearance and Diameter.

[5] W. Zhou et al. In the stave cooling of blast furnace study on hot face. Between gas flow and inlaid brick they use two equivalent coefficient, and stave and gas flow body. Heat transfer numerical calculation increases the accuracy about equivalent convection coefficient.

[6] W.Lijun et al. Basic fundamental is mathematical model of blast furnace stave and developed intelligent technique of simulation this simulation intelligent model of cast steel stave cooler is based on correction factor of parameter obtained by training the samples of test data of the cast steel cooling stave for study of intelligent monitoring methodology. The experimental data is nearly consistent with intelligent simulation model found.

[7] K. Verscheure et al. Pyrometallurgical processes is new processes for cooling of furnace is adopted by K. Verscheure is new technology .In the blast furnace, furnace cooling is very important, in the pyrometallurgical industry as it can increase productivity rate which is key, campaign life of furnace intensities process. Aspect of furnace monitoring material selection, manufacturing at different cooling design used non-ferrous and ferrous and alloying industry, when using water cooling refractory water quality.

[8] U. Pückoff and CH. Knoche. For cool the shell of blast furnace bosh, belly and stack it use various techniques. The cooling of boxes of varying design in earlier time, to a cooling medium

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the transferring of the west heat of furnace by number and size exclusively, with external cooling main is conjunction, stave is defined as cast iron plates cooler in during 1970s, furnace cooling is very important for attained worldwide. By cooling medium cooling of furnace shell almost gap free internal cooling, the plates which have area is considerable which are traveled by cooling medium. Origination of stave is originally from soviet discovery, there development of work has been no shortage, cast and cooling pipe materials they adapted, most condition of stress in modern larger high-performance blast furnace with the overall plate construction and installation.

[9] Yung-Chang Ko at al. To calculate the distribution of temperature of the hearth, model blast furnace is 2-D and for calculating of profile of temperature. During mud-plugging and taping temperature distribution show in the 2-D case. On temperature is not remarkable at bottom of hearth when effect of mud sintered time after plugging. A blast furnace model of hearth is considered the thermal analysis in term of mud and refractory in area of tat hole with the use of CFD Fluent.

[10] Todd Smith. Smith has been developed new method line of furnace is developed with demand; life of blast furnace is increase. To designing a new system the life of blast furnace is increase by maintaining more and more uniform temperature and the components characteristics strength is enhance. A very new system is design stave and double locks system of refractory combination specifically to overcome distortion.

[11] Lijun Wu at al. Between flow of gas in blast furnace and stave body hot surface calculation for models convection coefficient is equivalent, when temperature range of 505 to 1248^{o}c the numerical and experimental calculation combination established for flow of gas and in-laid

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bricks. When temperature of gas is high the coefficient of heat transfer between in-laid bricks and flow of gas is much more effective than that stave and gas.

[12] Maria Swartlig. To determining the flow of heat in a production hearth of blast furnace study is only concentrate on heat flow. In the blast furnace in this part temperature is expose to high. The flow of heat are needed for increase the effective length of the lining. Study about both numerical and experimental in modeling of heat transfer. The relation measured between outer surface temperatures and lining temperature.

[13] David Roldan at al. The equations of governing of flow properties on a grid of computational and initial conditions with boundary is specified. Included the shell, refractory material, ram and hot metal in these works computational domain is three dimensional. To formulate the equation governing employed some assumption.

[14] G.X.Wang at al. In this paper calculation about mathematical model, with the use of finite element analysis method solution technique developed, the region of lower stack of blast furnace to reproduce the heat transfer of three dimensional models. To calculate the coefficients of overall heat transfer equation have been formulated for various boundary of heating of cooling.

[15] Jan Torrkulla and Henrik Saxen. The hearth of blast furnace is presented skull profiles and erosion estimation. On the measurements of thermocouple in the bottom hearth lining wall. Skull material thickness is presented severe of erosion in the lining during experience campaign. The data is taken from two blast furnaces. For the controlling the hearth of blast furnace some proposal are given.

[16] Kuncan ZHENG at al. The life of blast furnace is very important things in the production industry. The key factor in the blast furnace is lining erosion. The development of computer

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software and improvement of CDF, simulation with numerical already exist, in the blast furnace main way of study about erosion of refractory. Since 1960s lining corrosion in the blast furnace is determine by numerical simulation.

[17] S.B. Kuang at al. The environment of blast furnace is beneficial due to charging of iron bearing material and hot brings sufficient energy on iron making blast furnace. A small information about operation on blast furnace performance and flow is hot charging operation for quantitative effects. In this paper calculation of multiphase flow due to numerical solution. The hot charge operation is special reference in blast furnace operations. Under the different conditions top gas temperature and top gas efficiency is utilize.

[18] Dong Fu at al. The chemical reactor of counter current included increasing flow of gas and descending porous bed counter current in iron making blast furnace. For the calculation of blast furnace model a new method Computational Fluid Dynamics (CFD) is used to simulate the multiphase flow. Another burden layer on flow of gas a new methodology is propose novel methodology is effective, chemical reaction, mass transfer, heat transfer.

[19] Cheng su-sen at al. China introducing first time copper stave wall for blast furnace monitoring that has been design. Copper stave wall of blast furnace is monitoring program with the concept non-inverse and inverse problem combine method, can also use to compute the hot surface temperature and gating thickness of copper stave blast furnace thermocouple, by maintaining appropriate gating thickness. Both high productivity and long campaigns is achieved due to maintaining suitable thickness in the copper stave blast furnace.

[20] Cheng and Xie. Study about outcome of temperature variation of stave cooling, stress, temperature and distortion of displacement of stave cooling when gas temperature increase from

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1000 to 1600^{o}c inside the blast furnace. Increasing the temperature of the gas results that the cold side temperature field is under control. The rate of change with respect to time and temperature gradient are greater on hot side and the values can reach 100 ^{o}C/s. At middle portion hot surface stress is generated very large 400 MPs so due to very high stress there are so many creaks at this portion.

[21] Y. Kaymak . For the refractory lining material chosen and the geometrical design are complete understanding on thermo-mechanical performance. Under the various condition of refractory lining clearly need design engineer for efficient and fast computation of thermo-mechanical performance. In this process provide considerable faster models are provided, to achieve accuracy solution and preparation then traditional model is use.

[22] Akash Shrivastava and R.L. Himte. In this paper through heat transfer analysis the main aim is to analyze lining material behavior at different load by using software FEAM (finite element analysis method) called ANSYS. Bricks like high alumina bricks and silicon carbide two different type bricks are use for blast furnace cooling stave lining material also skull is considered two different type one is of negligible thickness and second one is certain thickness in is considered.

[23] Anil kumar at al. Thermal stress and heat transfer of blast furnace steel stave cooling is analyzed due to three dimensional model. Using FEM (finite element method)software ANSYS, temperature is calculated of cooling stave in thermal stress region. Lining material are compute are two different type. First one is silicon carbide and other one is high alumina bricks. The use of lining material at different-different load, from 773k to 1573k gas temperature, also skull in the stave use same gas temperature.

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[24] Maria Swartling. The study has concentrate on calculating the heat flow on production blast furnace hearth. Hearth in the blast furnace is at very high temperatures. When campaign length of lining is increase then lining improved heat flow, calculation of outer surface temperature in bottom part of blast furnace production carried out.

2.1 Summary

From the investigation of above journal, most of paper found that plan parameter of stave cooler and cooling curl utilizing reenactment and dissected the stave cooler at distinctive warm load from stack to midsection position for figure the basic temperature of hot surface of impact heater stave and temperature contrast of water in a stave cooler. In these papers did not contemplated about option medium for cool the recalcitrant covering and has not taken whatever other material with the exception of copper and cast iron for configuration stave cooler.

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CHAPTER 3

3-D MODELING OF BLAST FURNACE STAVE

Inside the blast furnace highest thermal zone is lower most zones. To maintain, repair and save the blast furnace the processes stave cooling is very important. Life key parameter for the blast furnace is cooling of stave. Inside the blast furnace main body of furnace is manufacture by steel and stave cooler is manufacture by cast steel. The thermal conductivity, melting temperature tensile strength and specific elongation of cast steel is high so that is use in stave.

3.1 Model of Blast Furnace staves cooling

Cooling stave arranged against the inner face of the shell between this last and the hard-headed covering satisfy a twofold capacity. The staves are made of steel, copper, cast iron components having an one loop or gathering of tubes in which the cooling liquid like a water or nitrogen flows. The cooling fluid, in the former workmanship, is a water, nitrogen, and nano fluid it is subjected to vaporization upon contact with the warmth flux which the fight cooler is to be concentrating.

3.2 Computational modeling of cooling stave

By the use of ANSYS® 15 software analysis the behavior of heat transfer at different load conditions for stave material this is the main objective. Through to ANSYS workbench 3-D stave cooling has been designed in the above problem, table 3.1and 3.2 respectively show in

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dimensions of stave cooler and cooling coil. After completing the modeling in workbench the file is export in AGDM file. After completing the three dimensional model in workbench open meshing, inside meshing when meshing is complete file can want to export in .MSH file. Then after completing of export in .MSH file that file import in FLUENT. In side FLUENT all material selection, assumption boundary conditions are given, the properties of material are show in table no 3.3. THE below figure 3.1show 3-D model of stave cooler, there are 2 hole shown in figure 3.2, these are the velocities inlet and pressure outlet of cooling pipe.

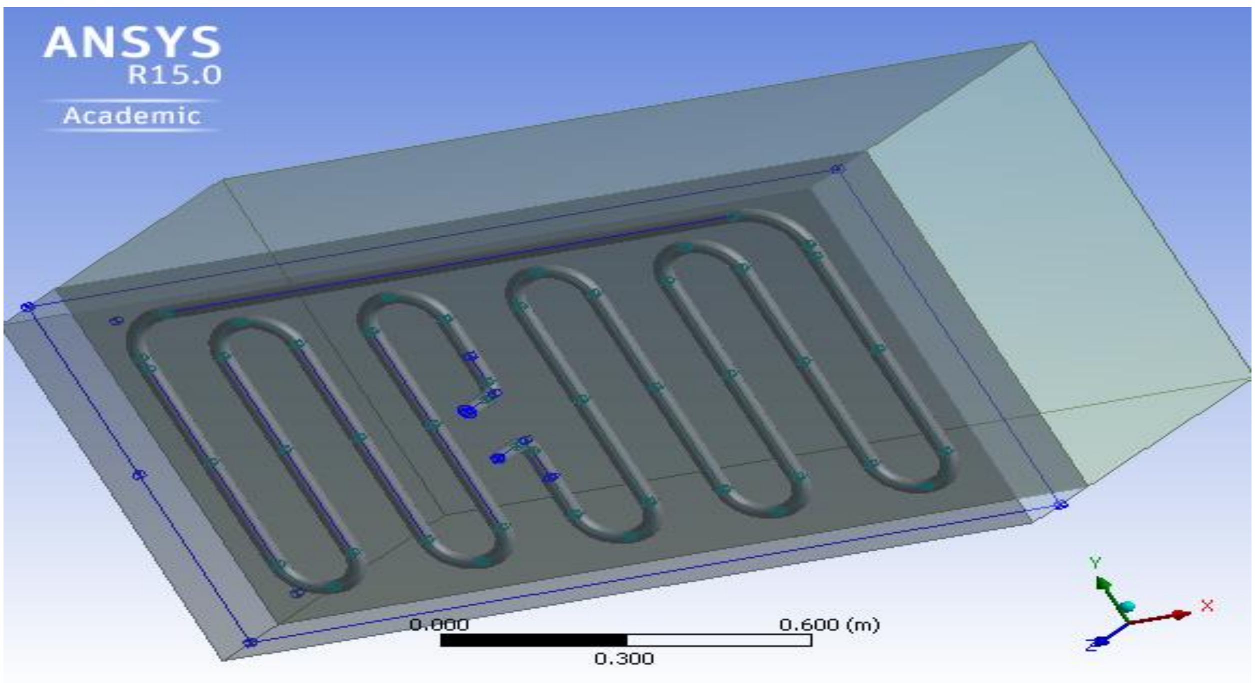

Figure 3.1 Three Dimensional Stave cooler of Blast Furnace

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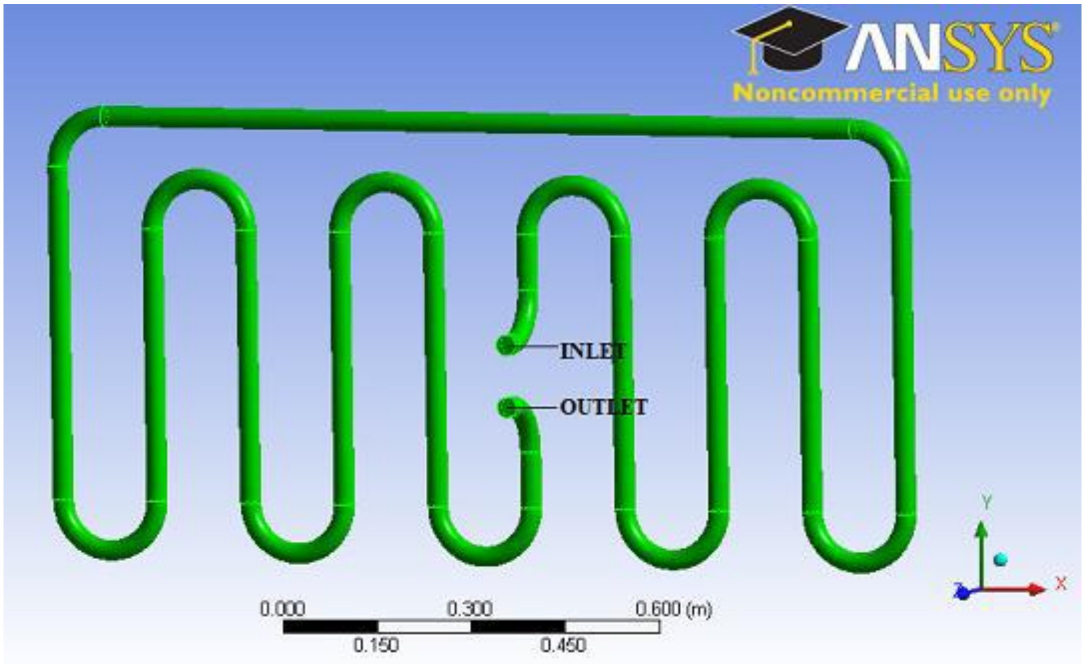

Figure 3.2 Cooling pipe of stave cooler

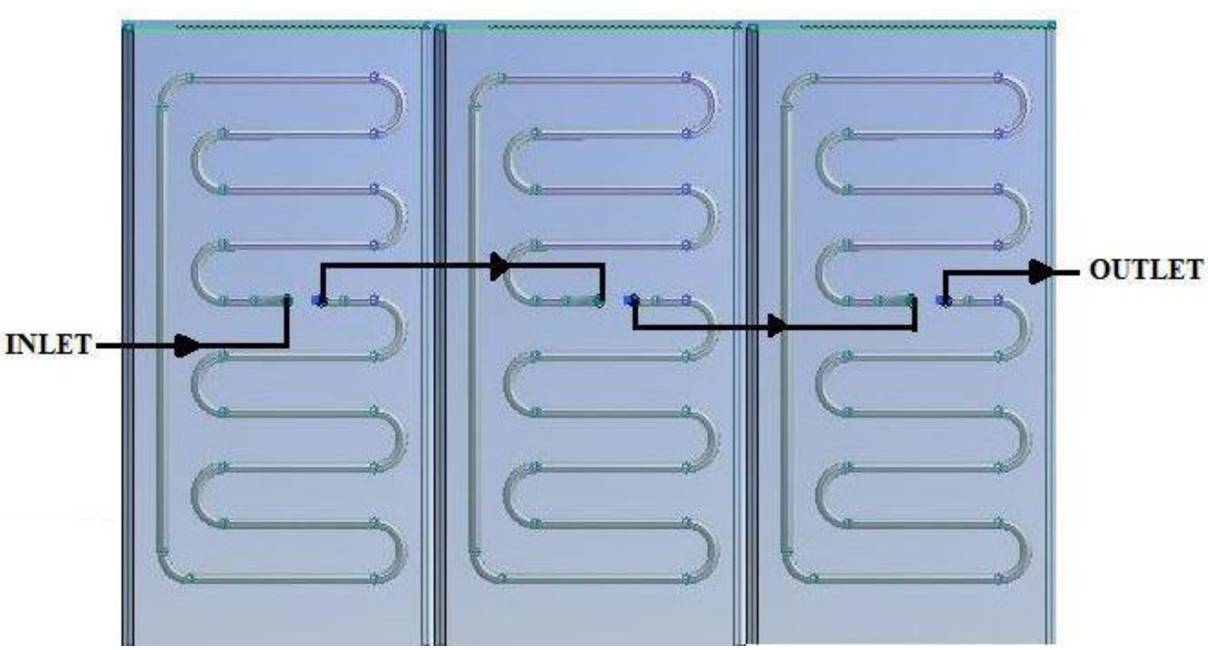

Figure 3.3 Stave cooler arrangement in Blast Furnace

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Arrangement of stave cooler is in loop, the Fig 3.3 show series connection of stave, how to join two or more than two stave. In this above figure one is inlet and another one is outlet when water is entering inside the loop of stave and water is coming at outlet. Than water or cooling fluid passed through hot staves to cool the blast furnace and then go to cooling tank after cool cooling fluid again come to stave and circulate cyclic processes.

Table 3.1 Dimension of Stave Cooler

Part	Thickness	Width	Height
Stave body	0.2m	0.9m	1.64m

Table 3.2 Dimension of casting coil in a stave

Part	Diameter	Length
Casting coil	0.33m	8.42m

Table 3.3 Different metal used in stave cooler

Metal	K(w/mk)	ρ(kg/m^3)	C_p(j/kgk)
Copper	387	8940	381
Cast iron	40	7500	460
Aluminum oxide	18	3690	880

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Table no 3.4 Fluid uses in blast furnace

	K(w/mk)	**ρ(kg/m^3)**	**C_p(j/kgk)**	**μ (N-s/m2)**
Nitrogen	0.02583	1.251	1040	0.00001663
Nano-fluid Al_2O_3 With water	1.17	1538	2597.555	1.5045

Fundamental equation for solving the fluid flow problem

1. Equation of continuity:-

$$\frac{\partial(\rho u)}{\partial x} + \frac{\partial(\rho v)}{\partial y} + \frac{\partial(\rho w)}{\partial z} = 0 \qquad (1)$$

This equation is valid for a fluid passing through an fixed control volume.

2. Navier-stokes Equation:

$$\rho\left(u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} + w\frac{\partial u}{\partial z}\right) = \rho x - \frac{\partial p}{\partial x} + \frac{1}{3}\mu\frac{\partial}{\partial x}\left(\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z}\right) + \mu\nabla^2 u \qquad (2)$$

Above equation 2 got from Newton's Law of Motion to a liquid component and is likewise called the momentum equation. It is utilized to model turbulent stream, where the liquid parameters are translated as time-arrived at the midpoint of qualities.

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$$\rho c_p\left(u\frac{\partial T}{\partial x}+v\frac{\partial T}{\partial y}+w\frac{\partial T}{\partial z}\right)=\left(u\frac{\partial \rho}{\partial x}+v\frac{\partial \rho}{\partial y}+w\frac{\partial \rho}{\partial z}\right)+k\nabla^2 T+\mu\phi \tag{3}$$

Where

$$\phi=2\left[\left(\frac{\partial u}{\partial x}\right)^2+\left(\frac{\partial v}{\partial y}\right)^2+\left(\frac{\partial w}{\partial z}\right)^2\right]+\left[\left(\frac{\partial u}{\partial y}+\frac{\partial v}{\partial x}\right)^2+\left(\frac{\partial v}{\partial z}+\frac{\partial w}{\partial y}\right)^2+\left(\frac{\partial w}{\partial x}+\frac{\partial u}{\partial z}\right)^2\right]-\frac{2}{3}\left[\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}+\frac{\partial w}{\partial z}\right]^2$$

These above equation are used to solve the fluid flow problem using the finite volume method in a fluent, generally energy equation is used in this problem for finding the outer temperature of stave cooler**.**

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CHAPTER 4

4 EXPERIMENTAL AND NUMRICAL ANLYSIS

This work done regarding the numerical analysis and modeling of real stave cooler utilize in Rourkela steel plant (RSP). On the basic of experiment stave cooler is identified, which is subjected to heat load is maximum inside the furnace. With the help of ANSYS software the three dimensional original model has been design taking all dimension from Rourkela steel plant stave cooler model. The design of stave cooler by ANSYS is same as RSP actual stave cooler. The real heat load is subjected to stave cooler in RSP measured by experimental setup. When heated load calculate by experiment and then put inside 3-D model in software ANSYS than conclude the difference of temperature same as in actual setup.

4.1 Numerical Analysis

In this project a 3-D model is taken and solve by numerical and steady the behavior of temperature of wall, inlet and outlet of stave cooler. On the one side of bricks heated flux is given, the wall of bricks and stave are coupled and also wall of stave and cooling pipe body is coupled. At inlet mass flow rate is taken of fluid.

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The steps for simulation and analysis are:

1. After importing the .msh file

2. The first step is the material selection. The material is selected for the stave body i.e. cast iron, copper.

3. The materials selected for Fluid i.e water or nitrogen

4. Then it has been given assumptions and boundary conditions to the stave cooler for the thermal calculations

5. Then it has been checked boundary condition of interface wall if couple wall come than it is correct.

6. Then it has given for iteration.

4.1.1 Assumption

1. Steady state conductive heat transfer process

2. Three Dimensional

4.1.2 Boundary conditions of stave cooler for thermal calculation

1. Wall of stave cooler assumed to be insulated except hot wall.

2. Heat flux has given on the hot wall of stave cooler.

3. Heat flux varied according to the position of Blast Furnaces.

4. Cooling fluid entered at constant temperature i.e 300K.

5. Mass flow rate has given to the inlet.

4.2 Experimental study

Experimental study of stave cooler is to calculate the actual heat load at experimental set up. In this set up of stave cooler two temperature reading device measure the temperature at inlet and outlet. For calculating the volume flow rate of cooling fluid flow meter are install at inlet of stave cooler. For the measurement of flow pressure of fluid is calculated by pressure gauge, the pressure gauge is installed in fluid flow line. The arrangement of nitrogen sufficiently by the RSP (Rourkela Steel Plant) near the stave cooler cooling system for experimental study. A device thermocouple to measure temperature of wall surface is set at wall surface of stave cooler. We have done some test work with diverse stave cooler in the bosh and hearth zone of an impact heater.

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4.3 Formula used for calculation

$$Q = \quad K \quad A \quad - \qquad (4)$$

The above equation 4 is called as Fourier Laws of Heat conduction, which was utilized to ascertain aggregate warmth strike on a hot face of stave. Negative sign demonstrate the diminishing temperature along with the bearing of expanding thickness or the heading of warmth stream

$$q \quad - \qquad (5)$$

The ratio of heat and surface area is defined as heat flux, equation no 5 is used to calculate the heat flux on hot surface of stave body.

$$Q \quad mc_p dt \qquad (6)$$

4.4 Summary of Experiments

The life of stave cooler is essential for blast furnace so analysis is done. With the help of thermocouple we are measure the temperature at outlet and inlet from experimental setup and calculation of heat with the use of equation no 6.

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CHAPTER 5

5 .1 RESULTS AND DISCUSSION

The result like heat flux, temperature variation is of stave cooler, experimental and analytical plot on graph. Calculation of actual temperature variation, heat flux with the use of experimental three dimensional model of stave, then after temperature variation of numerical model of stave cooler match to stave cooler running in RSP Blast Furnace, the study has been done with the use of cooling fluid neon fluid, water, nitrogen. In the calculation of heat flux, temperature variation cooling fluid mass flow rate is same for all coolant you can observed stave cooling by the water is better than nitrogen because of thermal conductivity of water is nearly four times than nitrogen, when mass flow rate of nitrogen is four times than water heat flux and temperature variation nearly same. When another cooling fluid neon fluid (Al_2O_3 with water volume by volume 20:80) is use the temperature variation and heat flux better result than water and nitrogen. The result calculating from numerical model stave cooler is same as result calculating with experimental. In the stave cooler different types of material are used like cooper and cast iron for analysis, than we found that copper is better than other material because the thermal conductivity of cooper is greater than other material.

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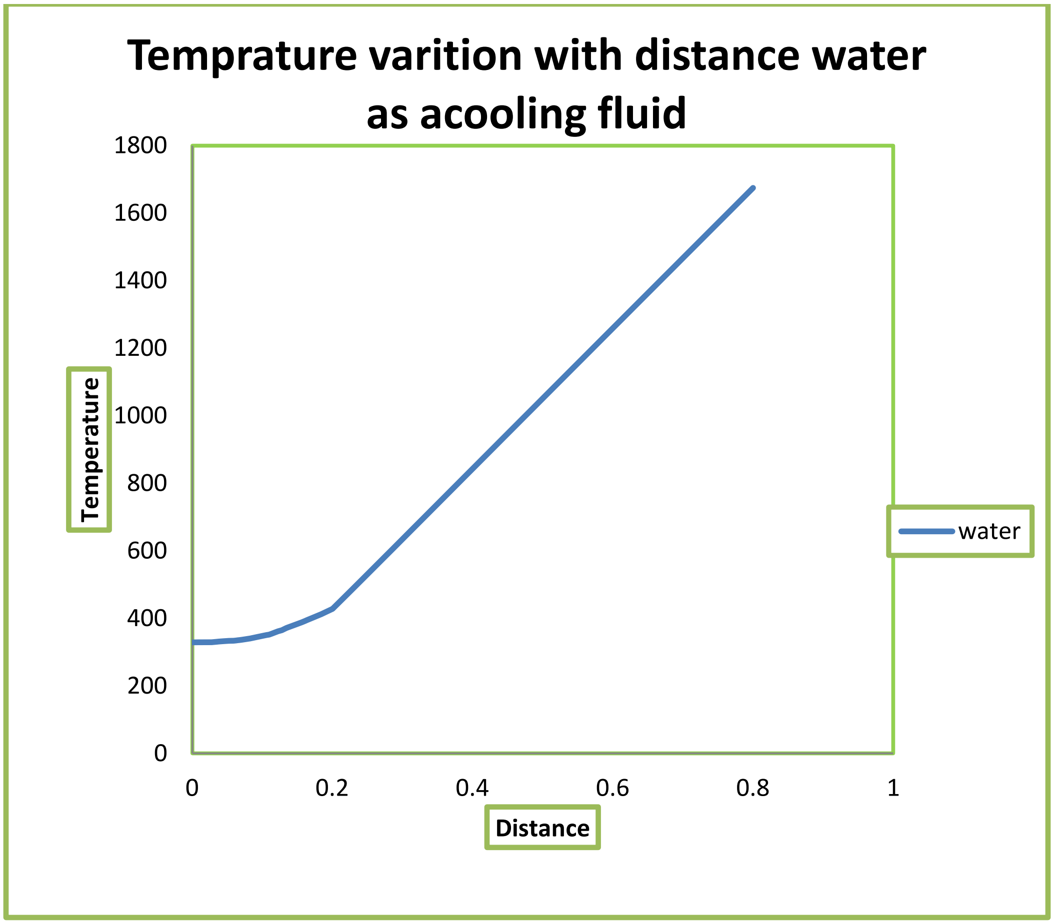

Figure 5.1 Temperature varition with distance

The distance from 0 to 0.2m is stave coler and 0.2 to 0.8m is bricks, when water is as use cooling fluid. The cooling of stave is faster then bricks.

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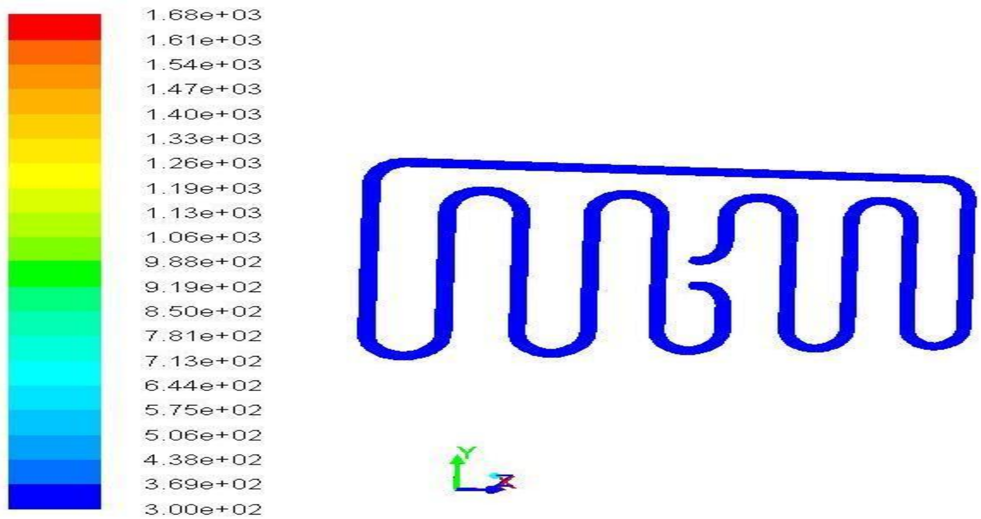

Figure 5.2 Temperature contour of pipe inside the stave without thickness

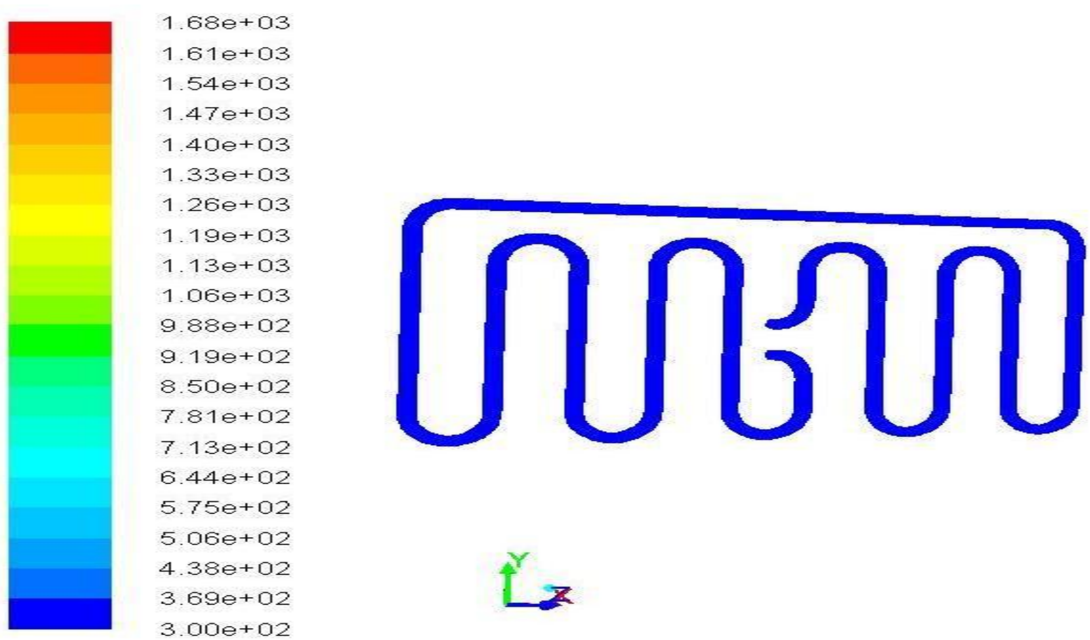

Figure5.3 Temperature contour of pipe inside the stave with thickness

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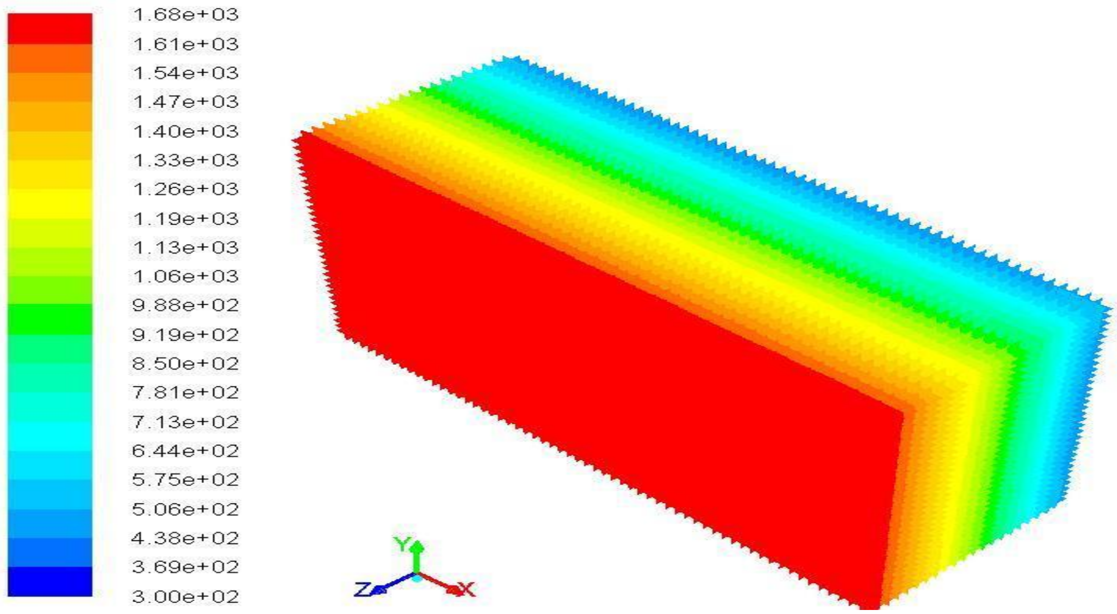

Figure5.4 Temperature contour of only bricks

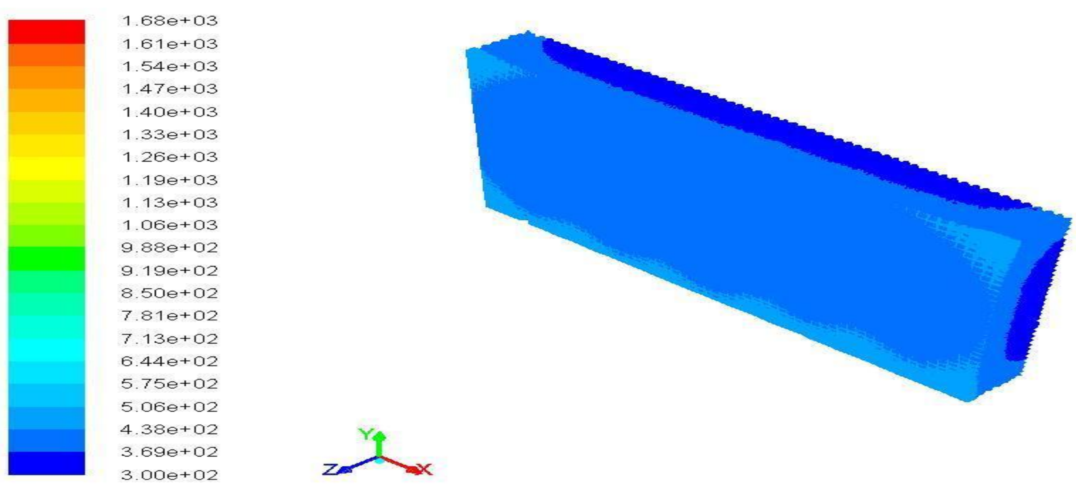

Figure 5.5 Temperature contour of only stave

5.2 Comparison when material of stave is cast iron and copper

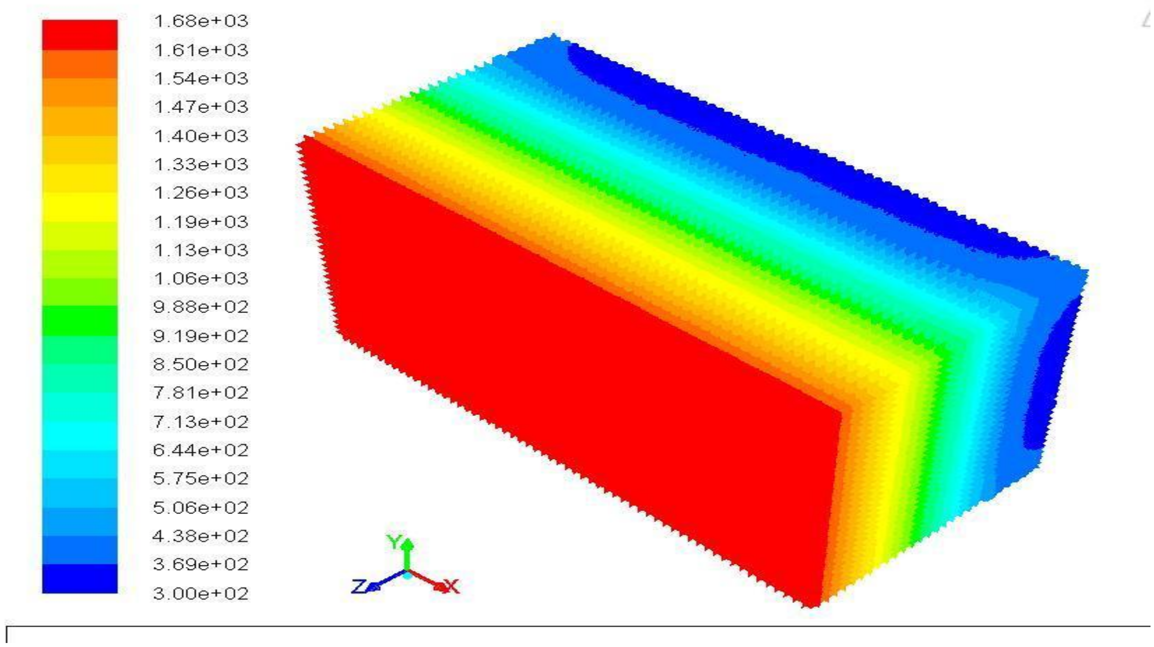

Figure 5.6 Temperature contour of stave cooler, stave is of cast iron

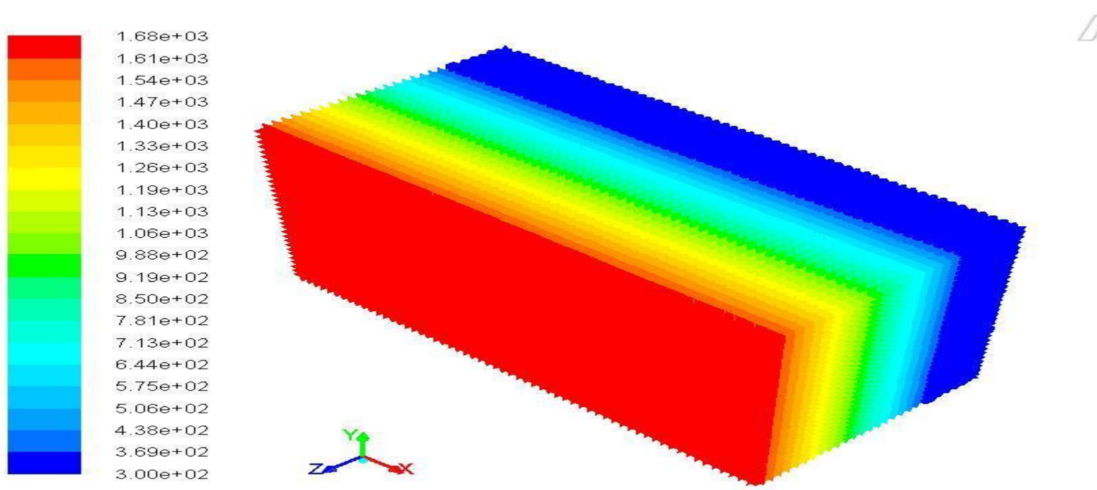

Figure 5.7 Temperature contour of stave cooler, stave is of cooper

Comparison between above two temperature contour the difference when stave is of copper the cooling is very festally in portion stave but when stave is of cast iron cooling is slower then stave

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is of copper. So when stave is of copper the life of stave is longer and cooling is of blast furnace is very festally.

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CHAPTER 6

CONCLUSIONS

The complete conclusion of this work is achieved on the basis of some boundary conditions, some parameter, assumptions all the result has been achieved. From RSP (Rourkela Steel Plant) all the data has been taken. Thus on the basis of this project 3-D model of blast furnace is taken and compression with experimental model in RSP, at different thermal loads from 500k to 1675k the behavior of stave cooler with finite element analysis method. We study about three verity of material use like copper, cast iron and aluminum oxide for consideration of stave material of blast furnace.

(1) Experimental data match with numerical data.

(2) Nano-fluid (Al_2O_3 with water) and Nitrogen effective cool better than water so these are the alternative cooling fluid in the place of water for cooling of blast furnace. Mass flow rate of nano-fluid and nitrogen is 2times and 10times respectively than water.

(3) One very important conclusions is conclude that when stave material is of copper the cooling of blast furnace very good and very festally other then any other material. Temperature on hot face of stave cooler of blast furnace is minimum when copper stave is use comparison to any other material. Because higher thermal conductivity.

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